SCIENCE BUSINESS LINE

The Department of Energy's investments in science are investments in America's future. Over the last half-century, our Nation's economic prosperity, quality of life, and security stemmed from strong public commitments to basic research. Most experts agree that publicly-funded science is expected to take on even greater importance in the new century. Public investments fill important gaps in scientific knowledge that are outside marketplace forces, and they build the scientific foundations for the technology breakthroughs of the future.

As the Nation's third largest government sponsor of basic research, DOE pushes the envelope of fundamental knowledge, attempting to unravel some of nature's most complex and stubborn scientific mysteries. The Department is a recognized leader in many of the *physical* sciences and makes substantial contributions in the fields of *computation, biology, chemical*, and *environmental* sciences through research efforts supportive of DOE's missions. The Department's accomplishments in science, along with those of its predecessor agencies, are partially reflected through its support to 68 Nobel Laureates from 1934 through 1998.

Powerful accelerators, light sources, neutron beam facilities, plasma and fusion science facilities, genome centers, and advanced computational centers are just some of the major instruments of science that distinguish DOE's capabilities and enhance the Nation's science base. These unique capabilities are needed for DOE's basic science mission. They also enable the Department to:

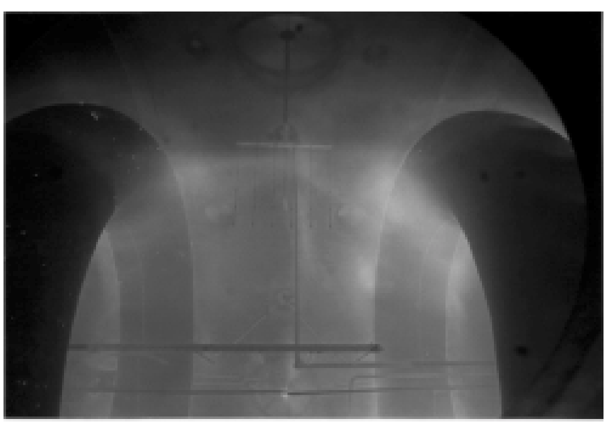
- Build the scientific foundations for advancement of new options for clean and affordable energy.
- Develop an understanding of the underlying phenomena and creates new options for managing the adverse health and environmental impacts associated with energy production and use.
- Seek deep insights and pursue new ways to control energy and matter at the most fundamental levels.
- Equip our Nation with some of the premier instruments of science and support a scientific workforce that will assure our continued leadership, prosperity, and security well into the 21st century.

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory will enable scientists to explore some of the most fundamental forms of matter by creating conditions similar to those at the creation of the Universe.

Situation Analysis

The discoveries and breakthroughs attained by DOE's science programs both contribute to fundamental scientific knowledge and provide the foundation for the applied research and technology programs within the Department. Fundamental scientific support for DOE's applied-science business lines is critically important. These research programs are directed at scientific and technological issues that are becoming more complex. To meet the challenges of the future, we need to explore entirely new approaches and options—not just evolutionary and incremental changes in technology.

Rapidly expanding economies and populations in developing nations will demand more energy, and many of the currently available energy sources have significant adverse environmental consequences on local, regional, and global scales. Basic energy research is needed as a foundation for improving technologies that can provide alternative forms of fuels; seek out new supplies of traditional fuels; convert known fuels to more efficient, environmentally benign forms; and generate, store, and transmit electricity with less waste. Fundamental science is also needed to track pollutants through their intricate interactions with the environment and to uncover new ways to dispose of toxins and reduce climate-changing greenhouse gases. Advances in scientific computation can be applied to enhance global climate modeling, analyze energy use, and test strategies for mitigating adverse effects of energy use. By unraveling the human genome and understanding the cellular environment, we will have the scientific foundation to develop capabilities to more rapidly detect and analyze chemical, biological, and nuclear threats. These complex challenges require cross-disciplinary approaches for both managing research projects and making substantial progress.



In fusion, the nuclei of two hydrogen isotopes are combined to form a helium nucleus, thereby releasing a large amount of energy. To control fusion on Earth, hydrogen must be compressed to high densities and heated to hundreds of millions of degrees. One approach, the tokamak (pictured here) confines the hot dense "plasma" with strong magnetic fields.

Scientific breakthroughs sponsored by DOE have also contributed to the start-up and growth of many new businesses and industries in the United States. Technology innovation continues to expand the market share of U.S. companies in the multi-hundred billion dollar per year global energy technology market. Business can now be conducted worldwide with a few keystrokes, using computing and communications tools based on advances in computational science and high-energy physics that were supported in part by DOE. New private-sector commercial activities have arisen in such public research areas as:

- Hydrogen-based energy systems;
- High-temperature superconducting wires and devices;
- Teraflop computers that set world benchmarks for speed;
- Medical diagnosis and imaging technologies;

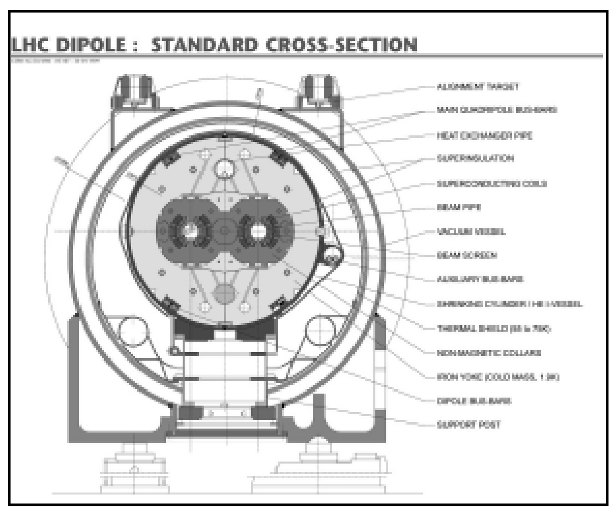
- Biomolecular design based on DNA sequencing;
- Portable energy storage; and
- Ion beam and plasma technology.

Scientific Excellence. With the current trend of reduced investment by industry in long-term basic research, government agencies are being called upon to assume more of the burden for the long-term well being of the Nation's science interests, and to deliver more for less. The imperative for the science community has never been greater to deliver the most valuable research within available budgets. To ensure value for the research dollar and excellence in performance, DOE depends on rigorous peer reviews and on scientific advisory committees. Peer review and advisory committees not only contribute to assuring the high quality of the work performed for DOE, they help the Department to recognize and track emerging trends and needs within the scientific community. This overall approach is recognized by many to be among the best and most thorough processes in the field of public research. DOE places a continued high priority on managing these processes well and searching out improvements and refinements that will further strengthen the Department's scientific management tools.

Multidisciplinary Research. The need for greater cooperation and synthesis across programs and disciplinary boundaries has become apparent as the scientific questions being asked grow increasingly complex and are tied to pressing societal issues. This evolution toward ever more multidisciplinary research requires new skills, greater teamwork, and new perspectives—all of which can be offered by scientists with interdisciplinary training. Accordingly, this Strategic Plan and DOE's science portfolio include various crosscutting initiatives, some of which were formulated during the planning processes. They and similar initiatives hold the keys to some of the most promising future areas of science.

International Collaborations. The trends toward increasing international collaboration in science raise issues regarding the roles and responsibilities of participating nations. If DOE is to be perceived by the international community as a dependable research partner, the Department must receive sufficient long-term, stable political and budgetary support to be able to make and live up to commitments for long-term science projects. Otherwise, we risk being excluded from important collaborative ventures that are in our national interest.

Integration of Science and Applied Research. DOE needs to achieve greater integration between basic and applied research programs. Highly participatory strategic planning processes, the development of science and technology roadmaps, and coordinated workshops that focus on integration all help to strengthen the linkages between science and its potential beneficiaries.



The Large Hadron Collider, now being built at the European Laboratory for Particle Physics (CERN) promises discoveries of great scientific importance that will advance our understanding of matter and energy. U.S. participation in this large international collaboration ensures full access for the U.S. research community to this frontier in physics.

Coordination Between Headquarters and Field Elements. To improve coordination between DOE Headquarters and its field elements, the Department is making a major effort to strengthen relationships, bring clarity to roles and responsibilities, and improve communications. The Office of Science is encouraging greater dialogue, accelerating its planning activities, and taking other steps to improve operations so that administrators and scientists throughout the complex function in a seamless, connected way.

Key External Factors

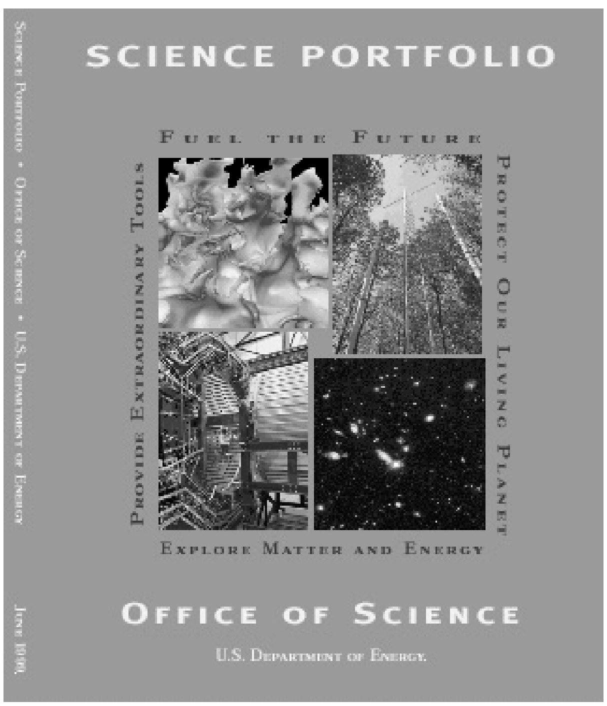
Despite large-scale downsizing and government-wide budget cuts over recent years, both the White House and the Congress have consistently supported science programs. This support reflects the widely held public view that basic research is important to U.S. competitiveness and long-term national interests. While there are differences from agency to agency, the budgets of most Federal programs and agencies have remained at least stable, and many have accommodated at least some modest growth when viewed against inflation. Continued and possibly expanded support is justified for Federal science programs given that there was a 38 percent decline in private-sector R&D spending by the 112 largest U.S. electric utilities between 1993 and 1996; that world energy consumption is projected to increase by four times the current levels within the 21st century; and that the pace of scientific discovery and technological advancement is accelerating, fostering fierce international competition for technological and market advantage. Continued support for DOE's science programs is anticipated, with modest increases expected over the near term. This factor will affect, to greater or lesser degrees, all of the four science objectives. President Clinton requested that the 1997 report from PCAST on the Nation's energy R&D portfolio "address the Nation's energy and environmental needs for the next century." DOE also launched a detailed effort to review the portfolio of science activities at DOE. This effort was based on a strategic framework informed by over a hundred of the Nation's leading scientists, technologists, planners, and futurists. Considering major external factors and core competencies of DOE, several important science themes emerged as part of the review effort and planning process, giving rise to focused discussions and greater attention on complex and adaptive systems, including nanotechnology; computation; and carbon sequestration, to name a few. Complex and adaptive systems impacts science Objective SC3. Computation is crosscutting, but strongly impacts Objective SC4 and, carbon sequestration impacts Objective SC2.

Interagency Crosscutting Coordination

Throughout DOE's programs in biological and environmental research, computational disciplines, and basic energy sciences, the Department coordinates closely with other agencies, especially in conducting science programs in which several agencies have specific roles. An example is the program to sequence the human genome. Additionally, DOE is a member of the Administration's National Science and Technology Council, which works to ensure interagency cooperation and coordination. DOE's partners include, but are not limited to the National Science Foundation, the National Institutes of Health, the National Aeronautics and Space Administration, and the Department of Defense. Additional information about the coordination and crosscutting activities with other Federal, State and local agencies is available in Appendix A.

Congressional and Stakeholder Consultations

The framework for the Science Business Line resulted from two national workshops held in 1998. They included the participation of more than a hundred leading scientists, technologists, high-tech managers, science communicators, and futurists from laboratories, other government agencies, Congress, DOE offices, and academic institutions. During post-workshop development of the strategic framework, the Director of DOE's Office of Science engaged in numerous conversations with the scientific community, the Congressional committees of jurisdiction, the Office of Management and Budget, and broader stakeholder communities.



The Science Portfolio is part of a broader DOE initiative to review all of the R&D, basic and applied, within DOE in light of our long-term strategic framework.

As the strategic planning progressed, interim versions of the framework were posted on the Web, and broad-based review and feedback were encouraged and received. Finally, DOE's major science advisory committees were briefed on the evolving product, and their responses were factored into the final version of this Plan.

Program Evaluation and Analyses

The Office of Science conducts extensive peer reviews and engages several advisory committees in its efforts to ensure that DOE programs are adequately reviewed and evaluated. Virtually all research projects supported by the Office of Science undergo regular peer review and merit evaluation based on procedures set down in 10 CFR Part 605 for the extramural grant program and in analogous processes established for the laboratory programs and scientific user facilities.

The Office of Science also makes extensive use of the six standing committees constituted under the Federal Advisory Committee Act—the Basic Energy Sciences Advisory Committee, the Biological and Environmental Research Advisory Committee, the High Energy Physics Advisory Panel, the Nuclear Science Advisory Committee, the Fusion Energy Sciences Advisory Committee, and the Advanced Scientific Computing Advisory Committee. Critical advice and valuable recommendations are regularly obtained from these committees of independent experts on program content, scientific quality, future directions, research priorities, and proposed scientific user facilities.

To develop the goals, objectives, and strategies contained within the Science Business Line, DOE drew on the participation of advisory committee members and many others, in two national workshops. Additionally, background and supporting concepts were raised and discussed in many sources from advisory committees, building on material and ideas contained in reports such as:

- *Planning for the Future of High Energy Physics: (February 1998).* A subpanel report of the High Energy Physics Advisory Panel.

- *Scientific Discovery through Computing: (March 2000).* A review and plan submitted to Congress on the computational needs of DOE science programs.

- *Nanoscale Science, Engineering and Technology Research Directions: (September 1999).* A study conducted in preparation for the national, interagency research initiative in nanotechnology.

- *Complex Systems–Science for the 21st Century: (August 1999).* A review of the issues, opportunities and plans for the science behind fundamental complex structures.

- *Human Genome Project Five Year Plan (1999-2003): (October 1998).* A collaborative plan developed during a series of DOE and National Institutes of Health workshops and advisory committee meetings.

- *Carbon Sequestration Research and Development: (December 1999).* A collaborative review and resulting science/technology roadmap developed by the Office of Science and the Office of Fossil Energy.

- *Priorities and Balance Within the Fusion Energy Sciences Program: (September 1999).* A review and evaluation of the balance, priorities, and long-range goals within the research program, prepared by the Fusion Energy Sciences Advisory Committee.

Additionally, the draft goals, objectives, and strategies were provided to the Advisory Committees for review and comment. Not only did documented reviews and evaluations serve to disseminate information about the strategic framework, but in addition, the reviewers and evaluators had an opportunity to participate and influence the outcome of the planning process. Project-level peer reviews (distinct from the Advisory Committee process) have had a strong bearing on the research priorities and funding allocations *within* individual strategies, rather than on the nature of the strategies.

Numerous authoritative studies have concluded that extensive use of milestones and quantitative measures are inappropriate for evaluating the progress of basic research. For example, the National Academy's Committee on Science, Engineering, and Public Policy report, *Evaluating Federal Research Programs: Research and the Government Performance and Results Act* (1999), states:

> *"For applied research programs, progress toward specified practical outcomes can usually be measured annually by using milestones and other fairly standard approaches common in industry and in some parts of the federal government. For basic research, in contrast, progress toward practical outcomes cannot be measured annually, and attempts to measure such progress annually can in fact be harmful. Basic research progress can be reported annually in terms of quality, leadership, and relevance to agency goals, but practical outcomes can be measured only against a far longer historical perspective."*

The Committee's recommendations include the following strong warning:

> *"The use of measurements needs to recognize what can and cannot be measured. Misuse of measurement can lead to strongly negative results; for example, measuring basic research on the basis of short-term relevance would be extremely destructive to quality work."*

The offices responsible for fundamental research programs within the Office of Science evaluate and analyze their research activities using qualitative peer review mechanisms. Although peer review is the paramount performance measure, some other appropriate measures are used in conjunction with peer review. These include selected quantitative indicators or metrics; customer evaluations of user facilities; milestones for construction projects; and qualitative assessments of the outcome of prior research, including those provided by historical retrospectives, annual program highlights, and high-profile reviews conducted by the National Academy of Sciences and other independent organizations.

Resource Requirements

With the modest increase over the past three years in DOE's science research budget, the Department has been able to selectively fund high-priority new initiatives while preserving, with some shifts in emphasis, the core research activities.

In the future, the need to keep pace with advances in science will require substantial modifications to existing instrumentation and, in many cases, completely new facilities. The associated additional costs cannot be accommodated within a largely level funding base. Additionally, many of the support facilities and buildings that are essential to the continuation of the science are aging and in disrepair—some as old as 50 years. The poor conditions of these general-purpose facilities have adverse implications for the safety, security, cost, and continuity of DOE's science laboratories. Further, it will be increasingly difficult, to attract and retain the next generation of qualified scientists under the current working conditions in such facilities.

Two important human resource issues are anticipated to strongly influence our science programs in the years to come. Each presents vulnerabilities and challenges that must be addressed. First, a recent study by the National Science and Technology Council projects possible shortfalls in the science and technology workforce of the future. This problem will affect both the private and public sector research communities. DOE co-chaired this study and will be proactive in helping to implement some of the solutions.

The second issue is of immediate concern to DOE's science programs. An alarmingly high percentage of Federal science program managers are already at retirement age or within one to two years of being eligible. This situation creates a high risk for the Science Program that has been difficult to address because of inherently lean operations and externally imposed staffing constraints. These constraints have limited the ability to create an effective succession plan. At risk is the critical experience in managing large, complex scientific programs, as well as vital institutional and historical knowledge vested with these senior technical staff. Because the exodus of these employees is likely to be concentrated over a short period of time, it will be a challenge to achieve the desired smooth transition to a younger workforce.

Finally, the international scientific community is growing more connected and the pace of science is being accelerated because of advances in computation and communication. By taking advantage of the latest technologies in these areas, which requires considerable resources, DOE stays at the forefront of research, creates opportunities for much more collaborative approaches to science, and provides wider and more timely dissemination of the vast amount of scientific information that the Department generates. Through investments in new capabilities in computation and communication, DOE is able to increase inter-laboratory collaboration, conduct experiments from remote locations, and use scientific simulation as a potential substitute for more costly experimentation.

SCIENCE GENERAL GOAL

Advance the basic research and instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.

DOE science programs lead the Nation in many of the physical sciences and contribute major advances in the biological, environmental, chemical, and computational sciences. These programs extend the frontiers of scientific knowledge in service to DOE's applied missions in energy resources, environmental quality, and national security, and in support of a fundamental science mission to explore the nature of matter and energy. The Department's programs directly support award-winning researchers, as well as provide access for many other scientists who, sponsored by other agencies, universities, not-for-profit institutions, and companies, utilize the Department's premier instruments of science for the benefit of the Nation.

OBJECTIVE SC1

Provide the leadership, foundations, and breakthroughs in the physical sciences that will sustain advancements in our Nation's quest for clean, affordable, and abundant energy.

Introduction

The science programs at DOE, discover basic knowledge and provide the foundation for the applied research and technology programs within the Department's Energy Resources Business Line. Sustained advances in technologies for energy production and energy efficiency are made possible by the long-term research conducted within the Office of Science's programs in Basic Energy Sciences, Fusion Energy Sciences, and Biological and Environmental Research. In particular, these science programs contribute to breakthroughs in the understanding of fundamental processes and phenomena in:

- chemistry;
- materials;
- plasmas and fusion;
- plant, microbial, and other forms of solar conversion;
- electrochemical sciences;
- combustion and catalysis;
- and many other relevant fields.

The research addresses key issues in the development of new fuels, clean and affordable electric power, and efficient energy use.

DOE's science programs serve as a cornerstone for U.S. leadership in many scientific disciplines. They are pursued through research programs at universities and national laboratories, and the research is conducted in cooperation and partnership with the applied research programs in DOE, other Federal science agencies, and industry.

The Objective's Measures

DOE has established the following performance measures. These measures provide the basis by which the Department will know it has achieved the objective, or is making progress toward it. These measures will be translated into annual targets for performance plans and budgets for the Department.

- Improve understanding of hydrogen-related surface chemistry leading to efficiency gains for hydrogen production and storage, and increased use of hydrogen both as a primary fuel and in fuel cells.

- Make advances in the synthesis of superconductivity materials that may lead to superconducting devices capable of operating at temperatures above 100ºK, magnetic fields above 4 tesla, or currents above 100,000 amperes per square centimeter for more efficient overall systems for the storage and transmission of electric power.

- Develop more adaptable, higher resolution seismic instrumentation, including new sources and detectors, and improved computer algorithms for tomographic imaging of hydrocarbon reservoirs and subsurface transport pathways.

- Advance electrolyte chemistry and improve understanding of ion solutions and surface chemistry that will lead to longer lasting, higher capacity, rechargeable batteries—even thinner and lighter than plastic wrap.

- Develop new metals and ceramics designed at the atomic level, capable of withstanding even greater levels of severe physical and chemical stresses and extremes of temperatures, leading to applications in manufacturing processes and power production.

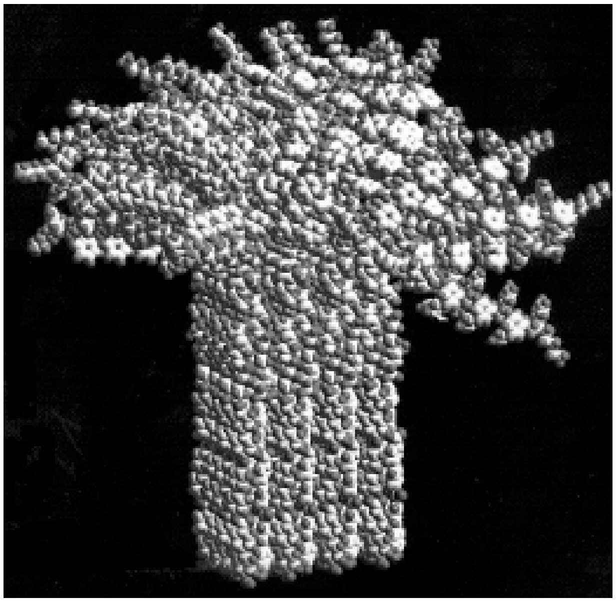
The Objective's Strategies

The following strategies describe the way in which the Department will work toward achieving this objective. These activities will be translated into annual budgets and performance plans for the Department.

- Advance the science for the development of new and improved sources of domestic fuels, with research emphasis on chemistry and materials science for energy conversion; plant, microbial, and solar conversion sciences; and geosciences.

- Explore the science that will lead to advanced generation, storage, and transmission of electricity, with research emphasis on metals, ceramics, and condensed matter physics; electrochemical sciences; and plasma science and fusion research.

- Develop the scientific foundations for cleaner, safer, and more efficient energy use, with research emphasis on combustion science, advanced materials for efficiency, engineering sciences, and new catalysis and chemical transformations.



The ability to control and manipulate materials at the atomic, or nanometer, level is ushering in an age of "Nanotechnology" with incredible promise for the U.S. economy. The self-assembling nanostructure pictured above forms an extremely thin film that is "sticky" on one side and "slippery" on the other.

OBJECTIVE SC2

Develop the scientific foundations to understand and protect our living planet from the adverse impacts of energy supply and use, support long-term environmental cleanup and management at DOE sites, and contribute core competencies to interagency research and national challenges in the biological and environmental sciences.

Introduction

The science programs of DOE—in particular Biological and Environmental Research and Basic Energy Sciences—contribute substantially to our fundamental understanding of the impacts of energy use (including energy by-products) on human health and on local and global environments. Such information is critically needed to assess the health and environmental challenges posed by different energy options, to formulate effective national policies in this area, and to investigate new energy alternatives that offer greater benefits with lower concomitant risks.

DOE science programs also underpin the Department's Environmental Quality Business Line. Research is pursued on long-term science issues that are pertinent to more effective and safer approaches to cleaning up DOE facilities, as well as options for the long-term management and final disposition of waste at DOE sites. Beyond these two important applications, the resulting scientific tools and capabilities often have broader research implications. DOE is frequently called upon to partner with other agencies in pursuit of other national life-science and environmental research challenges, including but not limited to activities such as the Human Genome Project.

The Objective's Measures

DOE has established the following performance measures. These measures provide the basis by which the Department will know it has achieved the objective, or is making progress toward it. These measures will be translated into annual targets for performance plans and budgets for the Department.

- Improve the spatial resolution of climate models used to simulate the dynamic behavior of the earth's ocean-atmosphere system from the current 300 km x 300 km to 150 km x 150 km.

- Improve the atmospheric transport and transformation models used to accurately and quantitatively predict the distribution and concentration of pollutants emitted from energy technologies into the atmosphere.

- Modify at least five microbes or microbial enzymes for potential use in cleaning up radioactive wastes, toxic pollutants, or modifying and upgrading fuel stocks.

- Improve the accuracy of biogeochemical models used to simulate both the net amount of carbon dioxide that is exchanged between the atmosphere and major terrestrial ecosystems each year and how much the net exchange is or would be affected by changes in vegetation or the way the land is used.

- Improve the understanding of the biomolecular effects of low-dose radiation, including genetic factors that determine individual sensitivity, to improve the scientific basis for protecting people and the environment from exposure to hazardous energy by-products.

- Develop at least five new radio-pharmaceuticals and the associated instrumentation needed for the precise imaging of gene function in the body; for the diagnosis of cancer, brain function, and heart diseases; for the staging of surgery; and for monitoring the progress of disease therapy.

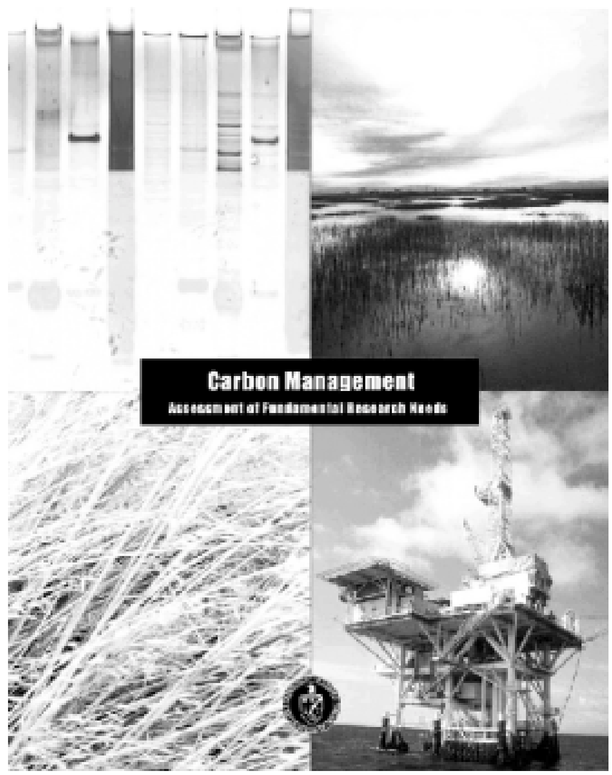
The Objective's Strategies

The following strategies describe the way in which the Department will work toward achieving this objective. These activities will be translated into annual budgets and performance plans for the Department.

- Improve our scientific understanding of the sources and fate of energy by-products, with research emphasis on sources and transport in the biosphere and on chemical interactions and transformations.

- Provide a basic understanding of the biology and ecology of energy by-products as they affect humans and the natural world, with research emphasis on human health impacts and risks, ecosystem and biological responses, and regional and global consequences.

- Create new science-based approaches that minimize energy by-products and protect the biosphere and human health, with research emphasis on pollution minimization, cleanup and remediation, carbon sequestration, and health protection regulation and medical research.



A first step toward understanding and perhaps mitigating climate change is an assessment of research needs. This report summarizes the five key areas DOE identified as needing additional research to better understand the complex interdependencies of the global climate.

Objective SC3

Explore matter and energy as elementary building blocks from atoms to life, expanding our knowledge of the most fundamental laws of nature spanning scales from the infinitesimally small to the infinitely large.

Introduction

DOE has a science mission to explore the nature of matter and energy at its most fundamental levels. Support from five science programs combine to address fundamental questions surrounding the essence of matter, time, energy, and space; nature and origins of the universe; building blocks of life; and complex and adaptive systems, some capable of self-assembly and ranging from plasmas and molecular systems of materials to living organisms. The supporting science programs include High Energy Physics, Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, and Fusion Energy Sciences.

Exploration of the nature of matter and energy is highly collaborative and DOE's endeavors will continue to benefit from many national and international partnerships. In the areas of High Energy Physics, Nuclear Physics, and Fusion Energy Sciences, the Department's research programs and advanced scientific instruments position the United States prominently as an international leader in these physical sciences. DOE's Basic Energy Sciences and the Biological and Environmental Research programs also exhibit leadership through their unique capabilities and research facilities and their special expertise in specific disciplines.

The Objective's Measures

DOE has established the following performance measures. These measures provide the basis by which the Department will know it has achieved the objective, or is making progress toward it. These measures will be translated into annual targets for performance plans and budgets for the Department.

- Confirm the existence of the Higgs boson and the first supersymmetric particles.

- Develop a quantitative understanding of how quarks and gluons provide the binding and spin of the nucleon based on quantum chromodynamics, further clarifying the theory of strong interaction as a component of the Standard Model.

- Prepare a coherent model of the origin and fate of the universe, supported by and consistent with observations of neutrino mass, cosmic background radiation, distant quasars and supernovas, and dark matter.

- Develop optical, ion, and plasma beam technology that can lead to electronic circuitry 10 times denser than that on today's chips.

- Complete a draft of the human DNA sequence by the end of 2000 and the entire sequence by 2003, as well as the genomes of many other animals and microbes, to provide the starting material needed to understand both normal and abnormal function including development, function, and disease.

- Validate new approaches and supporting science for plasma confinement and basic plasma phenomena, providing the foundations for possible energy applications.

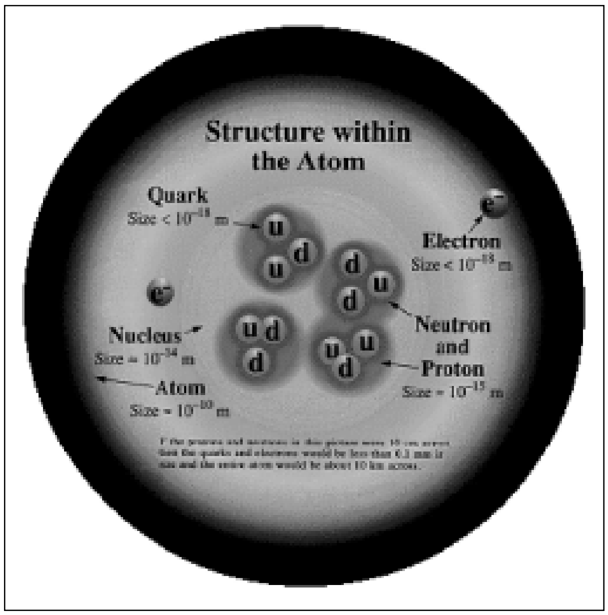
The Objective's Strategies

The following strategies describe the way in which the Department will work toward achieving this objective. These activities will be translated into annual budgets and performance plans for the Department.

- Advance the understanding of the nature of matter at the most fundamental level, with research emphasis on elementary particles and their interactions, nuclear matter and interactions, atoms and molecules, and biomolecular building blocks.

- Explore the evolution and fate of the universe through the fundamental relationships of energy, matter, time, and space, with research emphasis on the beginning of the cosmos, creation of nuclei and matter, evolution of astrophysical structures, and formation of life.

- Understand and improve our ability to control complex systems of matter, energy, and life, with research emphasis on complex phenomena and adaptive systems.



The "Standard Model" summarizes the current knowledge of Particle Physics. It is a theory that accounts for all observed particles and their interactions. It explains the forces that hold atoms and nuclei together or lead to their decay. More than three decades of theoretical and experimental efforts went into establishing this fundamental theory.

OBJECTIVE SC4

Provide the extraordinary tools, scientific workforce, and multidisciplinary research infrastructure that ensures success of DOE's science mission and supports our Nation's leadership in the physical, biological, environmental, and computational sciences.

Introduction

DOE plays a unique role in the Nation's science enterprise through its support of a broad variety of unique user facilities and laboratories, including large accelerators, experimental detectors and reactors, synchrotrons, massively parallel computers, high-capacity networks, and high-resolution microscopes. Thousands of scientists from DOE's national laboratories, from universities, private companies, and other agencies of the U.S. government use these extraordinary tools of science to advance the frontiers of knowledge. For many scientists, these facilities provide the only means for conducting the world-class research that has positioned the U.S. as a leader in the physical, biological, environmental, and computational sciences. The Department has a continued and important responsibility to maintain and nurture this infrastructure, along with the national laboratory system and the broader community of scientists that perform DOE's basic research.

The Objective's Measures

DOE has established the following performance measures. These measures provide the basis by which the Department will know it has achieved the objective, or is making progress toward it. These measures will be translated into annual targets for performance plans and budgets for the Department.

- Meet milestones for new accelerators, testbeds, and detectors for particle and nuclear physics, and (as supported by the physics communities) next-generation machines such as the Next Linear Collider, Muon Collider, Rare Isotope Accelerator, and advanced laser-based optical accelerators.

- Meet commitments and make progress toward new and upgraded probes and instruments for investigating materials, chemical processes, and life, including the completion of the Spallation Neutron Source, fourth-generation light sources such as free electron lasers and femtosecond x-ray lasers, and new accelerator and reactor designs for the production of research and medical isotopes.

- Create the software that enables parallel-processor supercomputers that are capable of petaflop speeds (a thousand trillion floating-point operations per second) to serve as powerful platforms for solutions to many complex problems and make these computers available to researchers working on problems critical to DOE's missions.

- Complete a needs assessment by early 2001, for modernizing DOE's science laboratories to ensure their continued viability to adequately support DOE research missions in the 21st century by correcting long-standing environmental, safety, health, facility, and infrastructure deficiencies, anticipating the changing nature and needs of research activities and achieving a world-class research setting.

- Implement effective programs for science education through fellowships in universities and colleges, teacher training for secondary schools, outreach to communities, and broad partnership programs in science and technology.

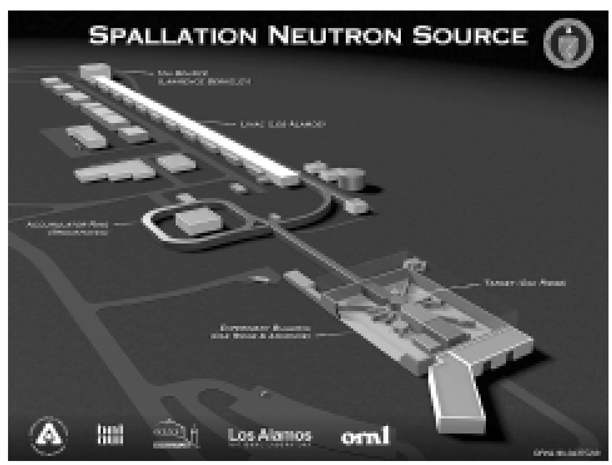
The Objective's Strategies

The following strategies describe the way in which the Department will work toward achieving this objective. These activities will be translated into annual budgets and performance plans for the Department.

- Provide leading research facilities and instrumentation that expand the frontiers of the physical and natural sciences, with emphasis on accelerators and detectors for high-energy and nuclear physics; light sources and neutron beam facilities; and specialized scientific facilities.

- Advance scientific computation and simulation as a fundamental tool for discovery, with emphasis on science applications software, ultra-high performance computation and communications facilities, and computer science and enabling technologies.

- Strengthen the Nation's institutional and human resources for basic science and multidisciplinary research, with emphasis on the national laboratory system, disciplines essential to our missions, scientific and technical information access and use, science education, and broadening the scope of research performers.



Complementing today's reactor and accelerator-based neutron sources, the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory is being built by a five-laboratory partnership to provide the most intense beam of neutrons in the world. Scientists will use this neutron beam to probe the properties of matter with extremely fine resolution for basic research and industrial applications in many fields from materials to medicine.

Linkage to Budget Structure

The Science goal is supported by four objectives. Each objective is being pursued through long-term strategies. The annual performance measures are discussed with the Decision Units in the Annual Performance Plan, which is submitted with the budget for each fiscal year. The following chart shows the relationship between Decision Units and objectives.